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UNPUBLISHED PRELIMINARY DATA

SUBJECT: A Bibliography on the Effects of Short-Wave and Particle Radiation on Glasses.

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## Introduction

Extraterrestrial observation of the solar corona outside of eclipse is limited by the presence of stray light within the coronagraph. The dominant part of this stray light arises from instrumental scattering, but in a space environment peculiar added sources of undesired radiance are to be contended with. These include fluorescence and scintillation of the glass lens elements due to short wave and high energy particle radiation. Discoloration of the primary objective might also prove to be a problem under these conditions.

The success of HAO's AOSO coronagraph system is dependent upon the minimization of these effects. It is the purpose of this memorandum to define the factors which are most likely to concern us in this connection and to provide, as a first step in the investigation of these phenomena, a bibliography of the information presently available in the literature to which HAO personnel have access.

*HAO Astro-Geophysical Memoranda provide an opportunity for the staff of our observatory to circulate for comment and criticism preliminary ideas not yet ready for formal publication, or not suitable for such publication. They are sent to our close colleagues at the Sacramento Peak Observatory and the National Bureau of Standards and to other workers with special interests in the field. They should not be regarded as formal publications.

## Definitions

### (1) Luminescence

Luminescence is a general term, used to describe light emission that cannot be directly attributed to the temperature of the emitting body. Various types of luminescence may be distinguished by attaching a prefix which suggests the source of the exciting energy that gives rise to the emission. An example is the familiar cathodoluminescence or electronoluminescence induced in the glass envelopes of cathode ray tubes.

### (2) Fluorescence and Phosphorescence

Many substances continue to luminesce for an extended period after the exciting energy is shut off. The delayed light emission is generally called phosphorescence; the light emitted during the period of excitation is generally called fluorescence. The luminous clock faces are well-known examples of the former effect while the purple glow of quartz under ultraviolet radiation is illustrative of the latter.

In an exact sense this classification based on persistance of the afterglow is not meaningful because it depends on the time resolution of the detector used to observe the luminescence. Hence, more precisely, fluorescence has also been defined as a luminescent emission having an afterglow duration which is temperature independent. Phosphorescence may then be defined as a luminescence with an afterglow duration which becomes shorter with increasing temperature.

For our purposes the first definitions are entirely adequate.

### (3) Thermoluminescence

Thermoluminescence is a term used broadly to mean any luminescence appearing in a material due to the application of heat.

Many solids contain one or more types of "centers" that can trap electrons. If such a material is exposed to light of sufficiently short wavelength, free electrons are produced within the solid and some of these may be trapped. If the potential well of the trap is sufficiently large, the electron cannot escape unless the temperature is raised. If heat is applied, however, it may acquire sufficient thermal energy to escape and result in a delayed luminescence.

HAO has proposed to protect the AOSO coronagraph optics from meteor pitting by using a protective door or shield, which will close when the system is inoperative. If this shield is not opaque to x-rays, this effect may be of importance in the AOSO application.

(4) Scintillation

The flashes of light from radiation emitted by atoms of a material as they return to their normal energy state after ionization or excitation by charged particles or x-rays comprise the phenomenon of scintillation. This is a fluorescent effect.

(5) Solarization

In the context of this memorandum, solarization is the well-known discoloration which is produced in glasses due to prolonged exposure to sunlight. Most common is the formation of a deep violet tint in ordinary glass. Serious solarization of optical elements is equivalent to the insertion of a broad-band optical filter whose density varies with time.

An investigation of the influence of these phenomena on the operation of the orbital coronagraph must consider the extent to which the presence of ultraviolet radiation, x-rays, and cosmic rays induces the following detrimental effects:

1. Fluorescence of lenses, mirrors, and other glass elements.
2. Thermoluminescence of the objective due to temperature rise upon removal of the shield and commencement of operation.
3. Scintillation in the optical elements.
4. Solarization of the lenses.

## Bibliography

### I. General References

(1) E. Hirschlaff
"Fluorescence and Phosphorence"
Chemical Publishing Co. of New York, Inc.
New York, 1938

Library number 535.3
H977f

A general, qualitative discussion of fluorescence with emphasis on its theory and characteristics in solids and liquid solutions.

(2) H. W. Leverenz
"An Introduction to the Luminescence of Solids"
J. Wiley and Sons, Inc. New York, 1950

Library number 535.3
L577i

This book constitutes an extensive discussion of luminescence, with considerable stress on the influence of atomic and molecular structure on the phenomenon. Particular attention is given to artificial (man-made) phosphors.

(3) P. Pringsheim
"Fluorescence and Phosphorescence"
Interscience Publishers, Inc.
New York, 1949

Library number QC
475
P74

A detailed and sophisticated discussion of virtually all phases of luminescence, this book provided, when published, a complete survey of the field. There is a brief section on the general luminescence of glasses and a number of isolated references to this subject.

(4) P. Pringsheim and M. Vogel
"Luminescence of Liquids and Solids"
Interscience Publishers, Inc.
New York, 1943

Library number 535.3
P9361

The authors provide a qualitative and basic discussion of fluorescence in general.

(5) F. Seitz and D. Turnbull (eds.)
"Solid State Physics," vol. 5, 97, 1957
Academic Press, Inc. New York 1957



This article provides a relatively recent, concise discussion of luminescence in solids.

## II. Effects of Short Wave and Particle Radiation

(6) Perry B. Alers
"Effects of Gamma Radiation on Cerium Bearing Phosphate Glasses"
JOSA 51, 1251, 1961

This paper cites the results of an investigation of the discoloration induced in glass by exposure to gamma radiation and the extent to which the presence of Cerium suppresses the effects of the radiation.

(7) Byurganovskaya and Orlov
"Formation of Color Centers in Sodium Silicate and Quartz Glasses under the Action of Gamma Radiation"
Optics and Spectroscopy 12, 151, 1962

This paper describes an investigation of the dependence of the intensity of induced absorption bands in fused quartz and sodium silicate glasses on the gamma-radiation dose.

(8) Kerster and Dwight
"Phosphorescence of Glass Solarized by Soft X-rays"
JOSA, 24, 285, 1934

The phosphorescence induced in soda-lime-magnesia window glass by exposure to soft x-rays is measured by the darkening of photographic film.

(9) Kreidl, N. J.
"Recent Studies of the Fluorescence of Glass"
JOSA, 35, 249, 1945

The character and intensity of fluorescence depends upon: (i) wave-length of incident uv. radiation, (ii) glass composition, (iii) structural changes in the glass due to heat treatments.

This paper treats in some detail the effects of the atomic structure and constituents on fluorescence. In crown and flint glasses, the intensity and frequency decrease markedly with increasing PbO content.

(10) N. J. Kreidl and J. R. Hensler
"Gamma Radiation Insensitive Optical Glasses"
JOSA, 47, 73, 1957

Specially developed optical glasses maintain their transparency under intense gamma ray exposures. Cerium is used to resist the discoloration. The paper points out that cerium is also effective against solarization by uv and x-rays.

(11) Linwood and Weyl
"The Fluorescence of Manganese in Glasses and Crystals"
JOSA, 32, 443, 1942

The presence of slight impurity traces of manganese in technical glasses produce a deep purple tint in the glass upon exposure to sunlight (solarization). This paper gives empirical data on the dependence of fluorescence on atomic structure, composition and temperature. It was found that increasing the percentage of manganese caused the fluorescence to first increase, and then decrease. This is a fairly generally result, true for most constituents, and is called "quenching".

(12) G. S. Monk
"The Coloration of Optical Materials by High Energy Radiations"
Argonne National Laboratory Report ANL-4536
July 31, 1950

This is a pertinent discussion of empirical investigations into the discoloration and fluorescence of many glasses. There is considerable discussion of the means of inhibiting these effects.

(13) Newkirk and Bohlin
"Reduction of Scattered Light in the Coronagraph"
Applied Optics, 2, 131, 1963

Glasses containing somewhat loosely bound ions of boron, barium, and lead within the $SiO_2$ network of the glass have strong absorption in the 2000 to 3000 Angström region, and show strong fluorescence. Good coronagraph lens glasses from the standpoint of scattering may be ruled out due to strong fluorescence: e.g., BSC-2 glass, $CaF2$, LF-4, Ba-SFS glasses.

(14) Nyswander and Cohn
"Measurements of Thermoluminescence of Glass Exposed to Light"
JOSA, 20, 131, 1930

After long exposures to sunlight, glass may become discoloured to an extent which depends on the glass composition and duration of exposure. By heating such exposed glasses to temperatures above 100° C very marked luminescence (thermoluminescence) may be observed. In some cases such luminescence can be detected after only 2 days exposure. The first coloration is evident in about 2 weeks.

(15) Wick and Slattery
"Thermoluminescence Excited by X-Rays"
JOSA, 16, 398, 1928

The authors find that x-rays caused sulphates of cadmium, sodium and zinc with slight amounts of manganese to give rise to bright luminescence upon heating to T=100°C. After exposure to the x-rays, all the materials were at least slightly phosphorescent at room temperature.

The induced thermoluminescence was of two types: (1) the intensity rises quickly to a maximum upon heating, and rapidly decays. (2) the intensity rises slowly, but lasts much longer than type (1).

Exposure to the x-rays caused some materials to fluoresce under uv radiation, that did not prior to exposure. The extent to which these effects might apply to glasses is not stated.

## III. The Measurement of Fluorescence

(16) W. Budde
"A Photomultiplier Circuit for Precision Spectrophotometry"
Applied Optics, 3, 69, 1964

A circuit is described which allows precision measurements of the anode current of photomultipliers. Using an EMI 9558B photomultiplier, precision of ± 0.02 per cent was obtained.

(17) Burdett and Jones
"The Photoelectric Measurement of Fluorescent Spectra"
JOSA, 37, 554, 1947

An attachment is described which permits the measurement of fluorescence spectra with the Beckman spectrophotometer.

(18) Huke, Heidel and Fassel
"Measurement of Fluorescent Spectra of Liquids with a Modified Beckman DU Spectrophotometer"
JOSA, 43, 400, 1953

A description is given of an attachment for the Beckman DU Spectrophotometer for measuring the fluorescent spectra emitted by liquids and solutions.

(19) N. Ooha
"Note on the Photometry of Fluorescent Materials"
JOSA, 53, 879, 1963

A simple optical diagram is given for the measurement of fluorescence, utilizing a photocell as detector.

(20) Price, Ferretti, Schwartz
"Sensitive Fluorophotometers"
JOSA, 39, 1053, 1949

A series of special sensitive fluorophotometers were developed, utilizing an $H_4$ mercury arc as source and the IP 21 Photomultiplier as a detector. These are discussed in this article.

(21) G. R. Price
"The Design and Construction of Sensitive Fluorophotometers"
Argonne National Laboratory Report ANL-4113

This is a detailed report describing general principles of fluorescence detection and including a quite complete description of the methods and components for the actual construction of a sensitive detector.

(22) Ray P. Teele
"Photometer for Luminescent Materials"
JOSA, 35, 373, 1945.

This paper describes an optical comparison photometer, basically simple and buildable.

## IV. References Unavailable in the HAO or Math-Physics Libraries

(23) L. Bruninghaus
"On the Red Fluorescence of Glass"
J. de Physique, 2 (7), 398, 1931

(24) M. Curie
"Phosphorescent Glasses"
Trans. Faraday Society 35, 114, 1939

(25) D. Dobischek
"Properties of Luminescent Glasses"
Thesis. University of Berlin (1934)

(26) N. J. Kreidl and J. R. Hensler
J. Am. Ceram. Soc. 38, 423, 1955

In addition, a final reference concerning ultraviolet transmitting glass should be included, because of the possibilities offered by such materials. It is well known that in order to fluoresce, a material must first absorb the exciting radiation. Consequently, the possibility of using glasses or other materials transparent in the ultraviolet range should be investigated. The pertinent reference is:

(27) A. M. Bishay
"Ultraviolet Transmitting Glass"
JOSA, 51, 702, 1961

## Conclusion

The foregoing references provide a fairly complete bibliography of the available, pertinent literature. Unfortunately, they contain little information that is directly applicable to our problem. There seems to be no report available of studies on the behaviour of coronagraph-type lens glasses under radiation conditions simulating those exterior to the atmosphere. This is not surprising since the era of optical experiments in space is really only a few years old and hence there has been little motivation for such specialized study. Furthermore, very few of the accomplished space experiments have been carried out in the visible portion of the spectrum.